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ABSTRACT

Constructivist classroom environments are characterized by student engagement in science processes and manipulating experimental materials with experiential teaching of specific science concepts. Constructivist classrooms are where teachers build models of students' science knowledge, students participate actively in determining the viability of their own constructions, learning is interactive, cooperative and collaborative. The philosophical, psychological and pedagogical models for science teaching within the paradigm of constructivism are congruent with encouraging both "hands-on" and "minds-on" approaches in science laboratories with respect to a number of issues which include: preparation, pacing, need for attention, negotiation of social norms and negotiation of meanings. Arising out of the constructivist epistemology, therefore, is the need to use negotiated learning pedagogy in a constructivist-oriented science classroom. Given the socially active nature of science laboratory classes characterized by the need to exchange information, the use of negotiated learning pedagogy is even more compelling. If negotiation is to become an integral part of science teaching, teachers need to know what it means and how to identify and classify types of negotiation which go on in their classes. At the moment, the literature indicates a void in this area which needs to be filled as science educators aspire to appropriate use of constructivist pedagogy for meaningful teaching and learning of science. This study therefore investigated the sorts of teacher/student negotiation which can occur in a school science laboratory and attempted to find out if the types of negotiation identified could be grouped meaningfully. Using a case study approach which utilized a participant observation technique, seven groupings of negotiation were identified from several learning events within science practical classes of a selected teacher. The implications of the results together with the difficulties associated with structuring a constructivist science class to accommodate negotiation as a significant part of science teaching strategies are discussed. (Author)

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The Role of Negotiation in a Constructivist-Oriented Hands-On and Minds-On Science Laboratory Classroom

by

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Abstract

Constructivist classroom environments are characterised by student engagement in science processes and manipulating experimental materials with experiential teaching of specific science concepts. Constructivist classrooms are where teachers build models of students' science knowledge, students participate actively in determining the viability of their own constructions, learning is interactive, cooperative and collaborative. The philosophical, psychological and pedagogical models for science teaching within the paradigm of constructivism are congruent with encouraging both "hands-on" and "minds-on" approaches in science laboratories with respect to a number of issues which include: preparation, pacing, need for attention, negotiation of social norms and negotiation of meanings. Arising out of the constructivist epistemology, therefore, is the need to use negotiated learning pedagogy in a constructivist-oriented science classroom. Given the socially active nature of science laboratory classes characterised by the need to exchange information, the use of negotiated learning pedagogy is even more compelling. If negotiation is to become an integral part of science teaching, teachers need to know what it means and how to identify and classify types of negotiation which go on in their classes. At the moment, the literature indicates a void in this area which needs to be filled as science educators aspire to appropriate use of constructivist pedagogy for meaningful teaching and learning of science. This study therefore investigated the sorts of teacher/student negotiation which can occur in a school science laboratory and attempted to find out if the types of negotiation identified could be grouped meaningfully. Using a case study approach which utilised a participant observation technique, seven groupings of negotiation were identified from several learning events within science practical classes of a selected teacher. The implications of the results together with the difficulties associated with structuring a constructivist science class to accommodate negotiation as a significant part of science teaching strategies are discussed.

Introduction and Theoretical Framework

Science education, according to Hodson (1993) can be conveniently seen as consisting of three major aspects: *learning science* (acquiring and developing conceptual and theoretical knowledge); *learning about science* (developing an understanding of the nature and methods of science, and an awareness of the complex interactions between science and society); and *doing science* (engaging in and developing expertise in scientific inquiry and problem-solving). Each of these aspects contributes to the development of society especially in the cultivation of scientific culture and the education of the future generation in the acquisition of the necessary knowledge, skills and attitudes for coping with the ever-demanding world we live in (Jegede, 1995). Like most human activities, science education has always sought to be guided by psychological and philosophical reasoning and justifications. Put in historical perspective, science education has progressed from positivism through rationalism to what has now established itself as the philosophical paradigm of constructivism. Similarly, from a psychological perspective, science education has moved from objectivism through inquiry learning to cognitive processing and conceptual change/development.

Constructivism, which now underlies most science education endeavours, emerged from a convergence of three major routes (Solomon, 1994). These are the theory of personal constructs (Kelly, 1955), the notion of Children's Science (Driver and Easley, 1978; von Glasersfeld, 1989; Osborne, Bell and Gilbert, 1983; Osborne and Freyberg, 1985; Osborne and Wittrock, 1983); and the social construction of knowledge (Vigotsky, 1978; Wheatley, 1991; Ernest, 1991; Habermas, 1984; Cobb, 1989; Solomon, 1989). To date, most of the work that has been done in the paradigm of constructivism (Duit, 1993) in science education is concerned with developing teaching approaches that facilitate students' conceptual development (Driver, 1988; Solomon, 1989; Cobb, 1989). This conceptual change research as stated by Taylor, Fraser and White (1994), highlights (a) the key role of students' prior knowledge in their development of new conceptual understandings; and (b) the reflective process of interpersonal negotiation of meaning within the consensual domain of the classroom community.

Although negotiation is part of our everyday activity, the philosophical and psychological climate of positivism and behaviourism, which have for a long time dominated classroom interactions, has excluded this activity as a way of learning and teaching. Verbal interactions which hitherto were restricted to the teacher handing down instructions or 'knowledge' to students, or in question and answer sessions as found through wait-time studies (see Rowe, 1974; Tobin, 1987; Duell, 1994;

Jegede and Olajide, 1995), are now shifting to what Cunningham (1991) calls argument, discussion, and debate as part of communal engagement in disciplined, critical thinking (Cole, 1992). The philosophical paradigm of constructivism stresses the social construction and negotiation of meaning as part of constructivist epistemology (Cobb, Yackel and Wood, 1992; Driver, 1990; Tobin, 1993; Wheatley, 1991). Justification for this has come from several areas ranging from psychology, philosophy and sociology to education. Wertsch and Toma (1992), in discussing the need for a sociocultural approach to learning in the classroom, have asserted that 'key aspects of mental functioning can be understood only by considering the social contexts in which they are embedded' Piaget (1970), for instance, using psychology and sociology as bases argued that 'the collective intellect is the social equilibrium resulting from interplay of the operations that enter into all co-operation.' Bruner's (1986) ideological shift to constructivism and social construction of meaning is exemplified by his relatively recent statement that "I have come increasingly to recognise that most learning in most settings is a communal activity, a sharing of culture.... it is this that leads me to emphasise not only discovery and invention but the importance of negotiation and sharing - in a word, of joint culture creating" (p. 127).

Formal schooling is a subculture of the larger society, in which school activity is situated practice (Hennessy, 1993) and a 'common knowledge' about concepts and ideas is meant to develop through organised activities (Edward and Mercer, 1987). In such a setting, cognitive apprenticeship becomes a viable mode of learning. Cognitive apprenticeship takes place in the context of peer interaction and collaboration and, according to Hennessy (1993), 'discussions and negotiation in group work situations will provoke a more meaningful engagement with the problem-solving processes that teachers want to encourage' (p.32). As opposed to the normal classroom situation in which individual learning, teacher dominance and little interaction take place, the science laboratory classroom allows, amongst other activities, discussions, interactions, collaboration, group work, co-operation and negotiation during practical work.

Debate about the rationale, relevance and orientation of practical work and laboratory experiments in science has gone on for decades. While a comprehensive discussion of all the arguments for and against cannot be conducted here, it needs to be mentioned that the debate has largely centred on whether practical/laboratory work plays a supportive or confirming role (Lock, 1988), whether it promotes transferable or specific skills (Jenkins, 1989) whether it could be justified in terms of training in scientific method (Layton, 1990), whether it should be individual or teacher demonstrated (Hofstein and Lunetta, 1982), and whether it should be confirmatory or be the core of science

learning process (Shulman and Tamir, 1973). The benefits accruing from hands-on practical and laboratory work in science have been very well documented in the literature. They include concept development and facilitating learning (van-den-Berg, 1994; McFadden, 1991); improving communication skills, psychomotor skills, computational skills, problem solving, cooperative learning; and other critical thinking skills (Tobin, 1990; Pedras, and Braukmann, 1991; Toh and Woolnough, 1994; Ambrosio, 1993); and increase in student cognitive and affective outcomes (McRobbie and Fraser, 1993). In a detailed review in which the goals of practical work were grouped into five broad categories, Hodson (1993) has called for an alternative approach which "entails (i) creating opportunities for students to explore their current understanding and evaluate the robustness of their models and theories in meeting the purposes of science, and (ii) providing suitable stimuli for development and change." (p. 107). In effect, Hodson is advocating for science laboratory teaching and learning situations consistent with constructivist pedagogy. Atkin and Helms (1993) also subscribed to this line of thought when they argued for a shift in science education research goals to better serve public and professional purposes.

Science activities designed for laboratory work in the non-constructivist classroom are characterised in the following ways: (i) the use of direct instructional strategies, (ii) teachers do not construct models of the students' reasoning, (iii) the teacher is the sole evaluator of students' learning, (iv) authority and control of the class is 'hijacked' by the teacher, and (v) the outcome of learning are relatively limited. In contrast, science activities designed for laboratory work in the constructivist classroom environment are characterised by the following: (i) student engagement in science inquiry processes and manipulation of experimental materials with experiential teaching of specific science concepts (Leonard, 1989); (ii) problem-based learning; (iii) teacher builds models of students' science knowledge; (iv) students participate actively in determining the viability of their own constructions; (v) learning is interactive, cooperative and collaborative; and (vi) because the philosophical, psychological and pedagogical models for science teaching are congruent, a concerted effort ensues to encourage both "hands-on" and "minds-on" approaches in science laboratories with respect to students' learning, preparation, pacing, need for attention, mistakes, critical and creative thinking (Schamel and Ayres, 1992), and (vii) negotiation of social norms and negotiation of meanings (Confrey, 1990; Csikszentmihalyi, 1990; Wheatley, 1993).

Negotiation plays a very significant and prominent role when instruction is based on constructivism (von Glasersfeld, 1987). According to Wheatley (1991), negotiation has some distinctive features and phases. First, successful group problem solving requires considerable negotiation of social

norms. Second, as social norms are negotiated, more attention can be focused on negotiating science meanings. Third, during small group problem activities, the teacher is engaged in conceptualizing individual and group activity. Fourth, the process of negotiation is quite complex. Fifth, a successful negotiation is reached when the two persons have no further reason to believe their positions are different (von Glasersfeld, 1984). Sixth, negotiation also requires the intention to negotiate. The advantages derivable from negotiation in the classroom are numerous. Bauersfeld (1991) believes that negotiation allows students to develop reflection and self-control, and allows students to become an integrated part of classroom communication. McCarthy (1991) indicates that negotiation is a process of empowerment and a way of developing learner responsibility. Negotiation is a classroom social practice in which teacher and students jointly and actively interact to arrive at some consensus of meaning, ascribable to an event. The culture of the classroom, the prior knowledge students bring into the class, the social etiquette prevailing in the class, and the responsibility of the teacher to set up and legitimise the process of negotiation, all contribute to the construction of meaning.

Hofstein (1988), in asserting that sufficient data do not exist, opined that laboratory instruction can play an important part in achieving some of the goals of science education. He therefore suggested that there is a need to search for teaching strategies in the laboratory that will promote instructional goals. In a similar vein, Nersessian (1989) alludes to the idea that the predominant ideology among science educators is that hands-on experience is at the heart of science learning. He lamented that, as important as laboratory experience is thought to be, there has been little systematic analysis of just what can be achieved in the science lab. Very little is available in the literature to address these calls, and especially the issues of how negotiation occurs within a constructivist science laboratory environment and whether groupings of types of negotiation are discernible. This study was intended to fill the chasm in the literature and thereby contribute to focussing attention on this important but apparently neglected area of constructivist pedagogy.

Arising out of constructivist epistemology is the need to use negotiated learning pedagogy in a constructivist-oriented science classroom. Given the socially active nature of science laboratory classes characterised by the need to exchange information, become physically and mentally involved with understanding the basis of science concepts, and manipulation of materials, the use of negotiated learning pedagogy is even more compelling. Therefore, in a situation in which students are granted some measure of autonomy to take decisions, plan and conduct science activities, what sorts of teacher/student negotiation occur? Furthermore, can these sorts of negotiation be grouped

meaningfully into types? The main objectives of this study, therefore, were to investigate the role of negotiation in science laboratory classrooms specifically focusing attention on finding answers to these questions.

Methods and Techniques

Selection of School, Video Recording and Data Source

In this 'qualitative case study' (Merriam, 1988) of a Grade 8 science class we used 'triangulation' methods (Denzin, 1988) to optimise the plausibility of our interpretations. Triangulation is a method of combining multiple perspectives in order to construct a richly coherent interpretation of events.

First, we used 'data triangulation' by reflecting on our observations of video recordings in the context of recorded teacher interviews and fieldnotes of classroom participant observations. Second, we used 'investigator triangulation', in which the two researchers and a research assistant independently and jointly observed the same data source, namely the video-recordings of several lessons. During our reflections on the data, we were mindful of the need to consider discrepant events and to avoid the temptation of reaching premature consensus. As a result, new interpretive categories emerged over time, and the unanticipated issue of classroom power relations arose as a major consideration for future studies of classroom negotiation.

The study was conducted largely in a retrospective mode because the researchers were unable to revisit the classroom or to re-interview the teacher. Therefore, the evidentiary warrant for the categorisation of types of negotiation lacks the (dis)confirming perspective of the teacher. Consequently, we have been careful to avoid imputing intentions to the teachers' actions beyond those that were evident to us in our previous classroom-based studies of his classroom learning environment and science teaching philosophy. Nevertheless, this study would have benefited from the addition of the teachers' critical response to the researchers' interpretive inferences. The study was conducted in three phases as follows:

Phase 1: Selection of Teacher and School

The teacher was selected because he had participated in an earlier study which had designed a paper-and-pencil instrument for monitoring constructivist learning environment (CLES: Taylor, Fraser &

White, 1994) and which had investigated the philosophy of science underpinning his teaching (Milne & Taylor, 1995). His science classes were involved in the trialing of the instrument. During that study, extensive classroom observations and teacher interviews indicated that he was an innovative science teacher who held a constructivist perspective, especially on the role of teacher-student negotiation. His junior school science lessons were very student-centred: mostly laboratory-based instructional activities that were designed and conducted collaboratively with students. In most classes, students worked in small groups on a range of laboratory experiments. Observation of the groups revealed the extent to which students negotiated the design and carrying out of their own experiments and the significance of their results. Later, in the whole-class forum, students negotiated meaning with the teacher and other students.

Phase 2: Video recording of science laboratory lessons

A professional film-making crew was involved in recording three lessons in the teacher's Grade 8 science class. Three cameras were used to record (1) whole-class teacher-student discourse, (2) individual teacher-student discourse, and (3) the discourse of small-group laboratory activities. The technical problem of recording the discourse of small-groups was addressed by using a mobile directional microphone.

Phase 3: Analysis of the video tapes

Data were collected from the video tapes of the science laboratory classes recorded for the study. Vignettes from the video tapes were critically examined and analysed to support assertions made by the researchers.

The analysis of the video tapes was undertaken after ascertaining a high level of reliability between the researchers about the identification of negotiation and grouping them into types. This was done through a number of steps including (i) initial joint viewing by the researchers of some segments of the tapes to determine common consensus of negotiation between the researchers, (ii) practice analysis by the researchers during several joint viewing sessions to categorise negotiation in the classes, (iii) separate individual viewing sessions by the researchers to validate types of negotiation, (iv) joint viewing sessions by the researchers to revalidate types of negotiation, (v) joint viewing to determine the characteristics of each type of negotiation identified, and (vi) confirmatory work

undertaken by a trained research assistant to ascertain the types of negotiation. The revalidation procedure is as detailed below.

Revalidation

The vignettes were critically analysed through five phases of orientation, observation, classification, reflection, and reporting by the research assistant to revalidate the type and location of negotiation previously identified by the researchers.

a) Orientation Phase

The initial phase of orientation included familiarisation with the report by the researchers and examination of the existing labels originally assigned to the seven types of negotiation. The identified types of negotiation were: (1). Unstructured Sharing; (2). Structured Sharing; (3). Questioning Responses; (4). You might be able to tell me; (5). Navigating around obstacles; (6). Questioning to (re) direct focus of activity; and (7). Shaping expectations (for alternative ideas).

b) Observation Phase

The observation phase occurred in a closed media viewing room where the videotaped lessons were observed from start to finish. Brief notes were recorded regarding types of negotiation and time codes.

c) Classification Phase

Approximately 18 hours were spent reviewing the videotape and synthesising the recorded information. During this phase types of negotiation, teacher-learner discourse (Whole-class; Individual teacher-student; Small-group laboratory activities): the sources of vignettes (Student; Teacher); and quotes (two to five vignettes; exact time codes) were critically reviewed and recorded in draft form.

d) Reflection Phase

The draft records were filed for a while. During this time, the research assistant deliberated and consulted with the researchers who reflected on the videotape material and classification of types of negotiation. It was interesting to note that one quote could fit into two types. An example of this occurs from time code 694 to 707 as it appears in both Type 3, 'Questioning Responses', and Type

5, 'Controlled Navigation'. The example in Questioning Responses highlights the empowered students who responded using reflective thinking. Whereas, the inclusion in 'Controlled Navigation' indicates that the students were navigating around obstacles by searching for a more feasible method to test an idea. In this example, the teacher stated, "Last week we talked about gently heating these things" and the student responded, "We did but it gently broke"..... Teacher response, "Well, was it a gentle heat around it or maybe even just with your hands, rubbing it like this?".

e) Reporting Phase

The final phase of reporting was dedicated to considering the tasks performed at each phase, checking and altering the information recorded in the report, and proof reading the final document.

The revalidation process provided another source of validity for the types of negotiation already identified. It also helped in the alterations made to the names originally given to types 4 to 7 in order to assign them more concise classification conventions. The new names became: Type 4, 'Student as Expert'; Type 5, 'Controlled Navigation'; Type 6, 'Clarified Questioning'; and Type 7, 'Prerogative Planning'.

Results and Discussion

A number of interesting results emerged from this study. These are discussed under three sections of Students' and teacher's gains from negotiation, What is and isn't negotiation, and Types of negotiation as follows:

Students' and teacher's gains from negotiation

First, the results of the study demonstrated that constructivism can be translated to practical application at the classroom level, and that it engenders an atmosphere for positive social interaction and free exchange of ideas amongst students and with the teacher. Second, classroom management within a constructivist framework is more demanding for the teacher who, although assuming a facilitative role, relies more on elaborate pre-laboratory activities, planning, and instinctive judgement. The teacher over time cultivates the habit of a 'good' listener. Third, once the teacher establishes and legitimises a negotiation process the students quickly 'catch on' and proceed to enter into negotiation of common ownership of meanings as well as adopt personal interpretations. Students developed self confidence, challenged the views of others in order to validate meaning, and respected the views of others within the classroom sub-culture.

What is and isn't negotiation

The study has revealed the two sides of the coin of negotiation in the classroom. We found negotiation is not and should not be: (i) telling the science 'truth' or facts, (ii) imposing community knowledge especially on neophyte learners, (iii) disregarding/disrespecting students' knowledge, and (iv) assuming students cannot develop their knowledge about issues and concepts. The study revealed that negotiation is: (i) promoting questioning about the purpose of learning, (ii) probing into the nature (the what and how) of learning, (iii) a process by which a group arrives at a common understanding, (iv) a process of sharing and interaction, and joint ownership of ideas and meaning with which everyone feels comfortable to identify, and (v) subjecting ideas to critical group scrutiny.

Types of negotiation

The study revealed seven major types of negotiation which commonly occurred in the science laboratory classroom. They are:

1. Unstructured Sharing - when an understanding between the teacher and students is reached as to how the activity of the day (or part of it) would be conducted. It is not predetermined but it is procedural and methodological, and occurs spontaneously.
2. Structured Sharing - when an understanding between the teacher and students is reached as to how the activity of the day (or part of it) would be conducted. It is structured, predetermined, and influenced by the teacher's ideas.
3. Questioning Responses - this type of negotiation helps students to shape their own ideas and questions and those of others in a reflective manner. The direction of this type of negotiation is usually from the known to the unknown.
4. Student as Expert - this type of negotiation capitalises on students generating ideas, and turning them into 'experts'. It demystifies the authoritarian role of the teacher and impresses it upon the students that no one is the sole custodian of knowledge.
5. Controlled Navigation - this is when negotiation is reached or aimed at in order to test an idea using a more feasible method, especially when an existing method fails to attract communal acceptance or when it does not work.
6. Clarified Questioning - this type of negotiation aims at clarifying the nature of a problem being investigated or redirecting the focus of an activity or anomalous finding, subjecting ideas to critical scrutiny, or helping students to shape questions for investigation.
7. Prerogative Planning - this type of negotiation is summative and often is used as a lead to the next activities to be carried out.

The types of negotiation, how they occurred and supporting vignettes are tabulated below. For each type of negotiation the teaching-learning environments are identified and the sources of vignettes are also indicated.

Curriculum Framework

The three practical class sessions were each conducted over a sixty minute time schedule. The main theme that was dealt with in the practical activities was air. Several aspects of air including air around us, the properties of air (eg., colour, volume, weight), what is air composed of, and air pressure were part of the activities undertaken. The activities and procedures for carrying them out during the practical lessons included four segments of a) Preparation and Housekeeping; b) Introduction; c) Hands-On Exercises; and d) Reflections, Applications, and Future Directions.

a) Preparation and Housekeeping

This segment was structured and predetermined by the teacher. Order Sheets were distributed and verbal instructions given to the students. Students were required to listen and then complete the Order Sheets. The teacher observed, assisted or suggested that students access their peers for further clarification.

b) Introduction

The teacher spontaneously introduced and shared methodological information on the topic of the day (air) with the students. The observational methodology consisted of four objectives a) observe a situation (book, diagram, picture); b) write a brief statement (The sky is blue.); c) pose a question (Why is the sky blue?); and d) use resources to find answers (books, teachers, students, people in the community).

c) Hands-On Exercises

Students were given 'experimental licence' to plan, conduct and record their experiments. The teacher encouraged the students to take control of their own experiments. The empowered students were required to plan, conduct, observe, discuss, clarify, redirect, reflect, question, seek solutions and record their experimental activities. During and at the end of this session, students discussed their experiences within small groups and the whole class.

d) Reflections, Applications, and Future Directions

The teacher encouraged the students to extend their mindset to larger conditions fuelled by air (eg. winds). Students were required to identify various types of winds; their locations; formation; and how their speed could be measured. In reference to the next session, the teacher challenged students to plan other experiments associated with air.

Typology of Negotiation Identified in Science Laboratory Classroom

Type 1: Unstructured Sharing

Definition/description: Collaborative, spontaneous decisions regarding the activity of the day
Procedures: Procedural, Methodological

Events in the Teacher-Learning Environment	Source	Vignettes
Whole-class	**Teacher**	1. "Sometimes from a book....even a picture book, you'll see something to do with air. It might be concerning clouds or something like this. It might even have grey clouds or white clouds. Something may twig to you as an observation. Write it down as an observation, rather than try to copy out notes. The point I am trying to make, what I think we tend to do is look at notes as the you beaut thing of science. What I am really after, is, you making questions out of what you are seeing."
Individual teacher-student	**Teacher**	2. "What do you think we could write after an observation? We have made an observation from some one else's experiment from a book, ..., from a diagram or a picture we have seen from some sort of observation. Isn't the sky is blue? What does it lead to , to you? ....Are you saying ....."
	Student	"Why it is?"
	Teacher	"What if you can't find out, why the sky is blue?" **Location:** 170 to 194
Individual teacher-student	**Teacher**	3. "Let's leave it at this. If you see something .... try not to write out a whole paragraph from a book. Try to make a short sentence that is an observation to you. Something that is clear. Ask a question about it. What would follow thirdly?"
	Student	"Some sort of answer."
	Teacher	"Where can we get some sort of answer?"
	Student	"Book."
	Teacher	"Maybe from a book. Sometimes a book is a bit hard to get it from."
	Student	"Teacher."
	Teacher	"Maybe from a teacher. What is the problem with asking me?"
	Student	"Everyone is asking you. You might not know the answer."
	Teacher	"I might not know. So, what can we do in these sorts of situations?"
	Student	"Books, teachers."
	Teacher	"But we are really trying to find out an answer to something. Other people, yes, someone in class, teachers who are better at the topic than me, or mums and dads who have a bit of an idea about it." **Location:** 195 to 223

Type 2: Structured Sharing

Definition/description: Collaborative, planned decisions regarding the activity of the day
Procedures: Structured, predetermined, teacher influenced

Events in the Teacher-Learning Environment	Source	Vignettes
Whole-class	**Teacher**	**1.** "Listen here for a moment, please. For today let's make do with a little disruption from your normal working positions. Sheree and Jenny, spread yourselves along that whole bench because my trays will be in use. I would like you to turn to a whole new page on this topic of air." **Location:** 20 to 40
Whole-class	**Teacher**	**2.** "Number one, in filling in these sheets, we need to make sure not only that [the teacher's] name goes here, but your own as well, right. This stops a lot of the arguments and fights that could possibly go on, as to who ordered what and so and so has grabbed my gear, right. That will be a big help with all our tray equipment. Get your name on the top. Secondly, put a line across the page, right. Just from corner to corner, a big scribble, right. That's finished with then and our Lab Technicians know that that sort of equipment can go away. We don't want one tray per person, we would have the whole bench going. With all the ordering of the equipment, we need to have it in one or two trays and work from those, okay. Jot down those two points in page 3 of your notes." **Location:** 70 to 97
Whole-class	**Teacher**	**3.** "Let's think of some things I have mentioned today, right. Listen, in our science lessons, let's look for simple things like observations. Observations from books, from experiments, from diagrams, from things you see outside. The wind moves the leaves - is an observation. What question does that pose to you? Try and write down a question that it might make. Thirdly, use lots of resources to try to get an answer." **Location:** 223 to 236

Type 3: Questioning Responses

Definition/description: Student empowered to shape individual and peer ideas and questions using reflective thinking.
Directions: Known to unknown

Events in the Teacher-Learning Environment	Source	Vignettes
Individual teacher-student	**Teacher**	**1.** "You've dropped a burning match. Is that correct?"
	Student	"When I put the match in it went out."
	Teacher	"Well what do you call that?"
	Student	"....."
	Teacher	"You've got an observation and whenever you've got an observation you've got an observation in science you can work from. What did you say when your match went out?" "....." "What's the question? OBSERVATION: The match went out. QUESTION: Why did the match go out? We have a question that can lead us to .....?"
	Student	"Answer."
	Teacher	"If that is correct, is it many possibilities, answers?"
	Student	"....."

	Teacher	"You said, 'Because there was no air at the bottom.' You are saying....."
	Student	"....."
	Teacher	"Perhaps there is no air. There is no air in here. What can we do to test so that we can see that this is full of air and not full of air. So this bit is missing down here ..... So this supports your answer. Some reason or other there is no air down here. Can we get all of this air out of here and see if it is equal to the volume of that."
	Teacher demonstrating concept using blackboard diagram	"Big jar, I am going to help you with this one because it's something here that we can do some good science in. Look try and empty the bubbles into this which is full of water-and measure the amount of air that comes out of it. See if that equals this. I don't know it's fairly hard. There might be some way we can measure the air in here, mightn't there? ..... Maybe it is a bit too hard..... What did you do to start with? In with the match, down here and what happened? ..... Never saw what happened. .....First match might have been a fluke! ..... What did this first match do?""......"
	Student	"It burnt, it might have been a fluke, or it might have been the fact that there was some air in there. Then you dropped in a second match.
	Teacher	Brilliant, Stuey, you're on the right track."
		Location: 463 to 555
Small-group laboratory activities	**Teacher**	**2.** "How long do you think it will take you, Chris?"
	Student	"I don't know. It could take awhile."
	Teacher	"What's it all about at the moment? Are you going to heat one of these up?"
	Student	"Yeah."
	Teacher	"Are these nice and safe, so the glass doesn't drop? ....."
		Location: 902 to 910
Small-group laboratory activities	**Teacher**	**3.** "Haven't seen you young ladies, today."
	Student	"....."
	Teacher	"Are you. What's the aim of it all?"
	Student	"To see if hot air rises?"
	Teacher	"Is it? .... What's that down here?"
	Student	"That's water."
	Teacher	"It might be the water rising."
	Student	"No, you see. ..... Water when it gets hot steam comes up and steam produces ....."
	Teacher	"So, steam rises."
	Student	"No, the pressure does it."
	Student	"No, hot air does it."
	Student	"No pressure."
	Teacher	"Pressure does it. Well we've got an argument here. Why have we got an argument?"
	Student	"We don't know what we are talking about."
	Teacher	"Well, you've got this far. You must have got this far with knowing a little bit about what you are doing. ..... Can we sort out this little problem?"
	Student	"Yes."
	Teacher	"What are you sort of aiming to show?"
	Student	"If hot air rises?"
	Teacher	"Why didn't you heat up the air then?"
	Student	"What we did, it cracks the beaker ...."
	Teacher	"Last week we talked about gently heating these things."
	Student	"We did but it gently broke."
	Teacher	"It still broke last week, did it? Up in the other room, goodness."
	Student	"....."
	Teacher	"Well, was it a gentle heat around it or maybe even just with your hands, rubbing it like this. These are fierce heating devices, you know."

	Student	"Put your glasses on."
	Teacher	"Well, why did we have an argument?"
	Teacher-students	"....."
	Teacher	"Every experiment is fine if you have a result and a conclusion. The result says what we have found out, here. Is it that the fact it could have been the air rising or it might have been something coming out of the water which rose? If I was doing this experiment again, I would try heating it. Then if you do it or not is up to you. You may want to go into another area. ..."
	Student	"We just did air."
	Teacher	At the same time think what you will be doing and ordering for Monday." **Location:** 674 to 722

Type 4: Student as Expert

Definition/description: You must be able to tell me? Student as expert.
Theory: No one is the sole custodian of knowledge

Events in the Teacher-Learning Environment	Source	Vignettes
Small-group laboratory	**Teacher**	**1.** "What's this all about?"
	Student	"Air pressure."
	Teacher	"It's all about air pressure. You're going to increase air pressure in that flask. When it heats up the air, what?"
	Student	"The air pressure on the inside increases probably from the pressure on the outside."
	Teacher	"What about that hot thing on our bench? .....Why was the string in there?"
	Student	"The string was to make the smoke to get in."
	Teacher	"Why do you want smoke in there? Because I thought you were going to increase air pressure by heating."
	Student	"Yeah that's what we want to see. Smoke, air or water got air pressure quicker, heated up quicker."
	Teacher	"By having something like that. So, this one didn't have anything in .....? QUESTION: So you want to find out which one produces most pressure!"
	Student	"OBSERVATION: Air, first. String, second. Water, third in 1 minute 16 seconds. ...."
	Teacher	"It wasn't how hard you pushed in the cork?"
	Student	"No."
	Teacher	"Are you convinced?"
	Student	"Yes."
	Teacher	"What made you convinced?"
	Student	"See, I did the same experiment last week."
	Teacher	"And you've produced the results twice in a row. Brilliant, that's not bad is it. .....So, a good Scientist. ..... makes some notes for people to see what's going on. It might lead you to another question that you might want to answer. Perhaps, on Monday and get your order form in and that sort of thing." **Location:** 611 to 668
Individual teacher-student	**Teacher**	**2.** "What's the good learning bit that's going to come out of it? ....."
	Student	".... How much air the flame takes to burn."
	Teacher	"Yeah. What's the variable. What's the thing which we keep changing to see if it's going to have some effect?"
	Student	"The size of the container."
	Teacher	"Yeah, brilliant. Now what would you predict?"
	Student	"The bigger the container the flame? Air?"
	Teacher	"And have you tried that yet?"
	Student	"No."

	Teacher	"Rip into that, because you could just about do that today." **Location:** 828 to 839

Type 5: Controlled Navigation

Definition/description: Navigating around obstacles by utilising a more feasible method to test an idea.

Events in the Teacher-Learning Environment	Source	Vignettes
Individual teacher-student	**Teacher**	1. "You can do or you may like to vary it, your experiment, in some way."
	Student	"I was going to do one of completely string with no smoke and see if there's less room inside it. If it builds up quicker." **Location:** 658 to 662
Small-group laboratory activities	**Teacher**	2. "What are you sort of aiming to show?"
	Student	"If hot air rises."
	Teacher	"Why didn't you heat up air then?"
	Student	"What we did, it cracks the beaker. ...."
	Teacher	"Last week we talked about gently heating these things."
	Student	"We did but it gently broke."
	Teacher	"It still broke last week, did it?" Up in the other room, goodness."
	Student	"....."
	Teacher	"Well, was it a gentle heat around it or maybe even just with your hands, rubbing it like this? These are very fierce heating devices, you know." **Location:** 694 to 707
Small-group laboratory activities	**Student**	3. "It's too big to go under this."
	Teacher	"Too big for, right. Well, we've got to design our experiment a little bit differently, don't we."
	Student	"....."
	Teacher	"Yeah, that's one possibility. Anything else?"
	Student	"There's no small candles."
	Teacher	"Small candles that's two."
	Student	"I don't know."
	Teacher	"Well, does it have to be that jar?"
	Student	"Yeah, there's no other bigger ones."
	Teacher	"So, is there anything we can do in today's lesson or do we have to restart for next Monday?"
	Student	"We'll do it today."
	Teacher	"Let's get on to it." **Location:** 728 to 741
Small-group laboratory activities	**Teacher**	4. "What's causing these to break?"
	Student	"Too hot."
	Teacher	"That is the hottest flame you can get. ..... What about your glasses? ..... What have you just learnt?"
	Student	"You don't put the cork back in as soon as it's taken off the flame. ....."
	Teacher	"Did you have your glasses on?"
	Student	"Yeah."
	Teacher	"You'd better have them on again, hey. ..... What else have we learnt from what just happened here?
	Student	"Keep your glasses on."
	Teacher	"I've tried to tell you something about the flame."
	Student	"Very, very hot."
	Teacher	"So what are you doing? What have you been learning here?
	Student	"Not to heat it too fiercely".
	Teacher	"If we were going to fire the same heat each time, we're going to get a

breakage"
Location: 769 to 797

Type 6: Clarified Questioning

Definition/description: Questioning to clarify, analyse, shape or redirect focus of investigation.

Events in the Teacher-Learning Environment	Source	Vignettes
Small-group laboratory activities	**Teacher**	**1.** "Did you hear what I said about notetaking, today? What's important with notetaking? Because if you have a whole paragraph of written out notes..... If you have all these notes written out, what do they mean to us? They may say various things to us like: air is colourless; air is odourless; air has nitrogen, hydrogen; air weighs how much per square something or others. Does it really mean anything to us?"
	Student	"No."
	Teacher	"What if we say air is colourless? What sort of question are we going to ask?"
	Student	"How does it get blue?"
	Teacher	".....If it is colourless, how does it get blue? Brilliant, I think you're getting there. Right, and then nutting out your answer. Don't you think, if you can just get one answer per day, we've learnt something? You all know your task for today?"
		Location: 288 to 317
Individual teacher-student	**Teacher**	**2.** "What do you want to go to the library for?"
	Student	"To write notes on air."
	Teacher	"What do you want to write notes down on air for?"
	Student	"To learn about air."
	Teacher	"Ah, what is the use of air? Yes you must know what you're all about. Otherwise, if you just go down there and you're turning over pages, you'll get no where..... What really turns you on about air?"
	Student	"How it is made?"
	Teacher	"How air is made? Does it get made? ..... You wanted to make air. Air is made. It's here. Is it made? ....Is it a bit too undefinable a question? Is it one we can come to later? Can we break that up into something a bit smaller? What's in air? Does that interest you? What did you plan for today?"
	Student	"....."
	Teacher	"Perhaps you ought to take up this task of the weight of air. Does it always weigh the same amount on various places of the earth?"
		Location: 318 to 384
Individual teacher-student	**Teacher**	**3.** "How long can a candle burn in a sealed container? Does it matter how big the sealed container is? Do you think it's important?"
	Student	"Yeah."
	Teacher	"Yes. Okay, that's something which you could add there. I like your whole idea."
	Student	"What is the result."
	Teacher	"Because, is a Scientist interested in how long it can burn?"
	Student	"Yeah."
	Teacher	"Why? ..... I mean does it mean anything to a Scientist? A candle can burn for one minute in a litre coke bottle. What does it mean?"
	Student	"Because you might have to do another experiment with air involved."
	Teacher	"That's right. Is that really going to be an earth shattering thing and am I going to give you a test? .... Is any man going to come up to you and ask how long can a candle burn in a litre coke bottle? ....."
	Student	"My .... comes into my class everyday and asks me that question."

Teacher	"Does he really. Okay. So, why doesn't he ask about two litre coke bottles?"
Student	"He can just divide the size into it."
Teacher	"What's the good learning bit that's going to come out of it? ....."
Student	".... How much air the flame takes to burn."
Teacher	"Yeah. What's the variable. What's the thing which we keep changing to see if it's going to have some effect?"
Student	"The size of the container."
Teacher	"Yeah, brilliant. Now what would you predict?"
Student	"The bigger the container the flame? Air?"
Teacher	"And have you tried that yet?"
Student	"No."
Teacher	"Rip into that, because you could just about do that today."
	Location: 804 to 839

Type 7: Prerogative Planning

Definition/description: Shaping expectations for alternative ideas resulting in planning for the next activities in the investigation.

Events in the Teacher-Learning Environment	Source	Vignettes
Individual teacher-student	**Teacher**	**1.** "And you've produced the results twice in a row. Brilliant, that's not bad is it. .....So, a good Scientist. ..... makes some notes for people to see what's going on. It might lead you to another question that you might want to answer. Perhaps, on Monday and get your order form in and that sort of thing." **Location:** 664 to 668
Small-group laboratory activities	**Teacher**	**2.** "Well, why did we have an argument?
	Student	"....."
	Teacher	"Every experiment is fine if you have a result and a conclusion. The result says what we have found out, here. Is it that the fact it could have been the air rising or it might have been something coming out of the water which rose? If I was doing this experiment again, I would try heating it. Then if you do it or not is up to you. You may want to go into another area. ..."
	Student	"We just did air."
	Teacher	"At the same time think what you will be doing and ordering for Monday." **Location:** 707 to 722
Individual teacher-student	**Teacher**	**3.** "Go and get your last experiment."
	Student	"You mean the written up one."
	Teacher	"Yes, that last one you've written up and what you've found out about it. And then, what you plan to go ahead with." **Location:** 798 to 803
Individual teacher-student	**Teacher**	**4.** "Is that an order? Good girl. Four balloons is that all you need? That's great. You know what your task is all about?"
	Student	"Yeah."
	Teacher	"And have you got a bit of a question and answer type thing or an experiment aim that you're going to work on?'
	Student	"If hot air form a Bunsen burner can blow up a balloon?"
	Teacher	"Gee, it will be interesting to see how you are going to design this. Get a piece of paper and give us a look at how you're going to do this." **Location:** 852 to 866
Whole-class	**Teacher**	**5.** "If there are some other things you want to do about air ..... Perhaps we

	could start to look at some things to do with winds. Willy willies, tornadoes. What are the other names we have in Australia for these sorts of winds?"
Student	"Dust Devil."
Teacher	"Dust Devil. Yes. Cockeyed Bob. What do we get at Freemantle? On the beach, particularly."
Student	"Freemantle ....."
Teacher	"Yeah, that's right, isn't it. Do we know anything about these and how they form and how we can measure the speed of them? What causes them? Anyhow, there must be lots and lots of things you can do in air. ....."
	Location: 971 to 992

The results of the study and the anecdotal data compiled by the researchers during the participant observation periods indicated that the use of negotiation in a constructivist science laboratory work can be used to focus attention on three major areas in science. First, it helps to show the students that within the scientific community, knowledge is negotiated using an interlocking grid of personal opinions, experiences and argument based on evidence and reasoned theoretical propositions. Second, it helps to teach the students that science is a corporate enterprise and the community which practises it has established ways of monitoring its manufactured knowledge (Ziman 1968; Solomon, 1994). Third, it demonstrates that science practical work within a constructivist framework, uses the ideas already in the minds of the students and also that classroom interactions significantly enhances negotiation as well as bring to the fore within a social environment students' alternative or indigenous knowledge that they have brought into the classroom. These, in part, support the findings of earlier studies on negotiation in some areas (DeVries ,1991; Mink, 1992; Davis, 1988; Wheatley, 1993).

However, although we do not have conclusive evidence, the results of this study point to some difficulty in the use of the constructivist pedagogy of negotiation in science laboratory work. The first major problem is the issue of power structure in the classroom under the new dispensation. In non-teaching settings, such as everyday discussion and interactions with friends or peers, negotiating partners often assume equal roles or, in some cases like family situations, the authoritarian role of the parents is understood. In a constructivist classroom, however, the teacher might continue to subconsciously adhere to the traditional power structure in which he/she is in total control or, if he/she is aware of the new ways of thinking, the teacher might devolve power to groups of students but feel threatened by 'letting go' of power. A second concern is that, within student groups, there are those who tend to dominate discussion by forcing their ideas on others rather than negotiating. The silence of others within the group, as a result of tiredness or some other reason can be easily misconstrued as agreement with the dominant (i.e., 'forced') ideas. O'Loughlin (1992) criticises

constructivist pedagogy because it does not adequately address the issues of culture and power in the classroom. One implication of this could be that social negotiation may not be uniformly beneficial to all the students and teacher. It could depend on some of the issues raised above and the way a teacher designs the class. Negotiating authority and group leadership is also implicated here and would form a fertile ground for further studies.

We observed that 'Structured Sharing' seems to be evidenced by teacher-directive discourse rather than teacher-student 'collaborative' discourse, and the negotiation seems to be implicit (ie students are expected to conform to procedures) rather than explicit (in which students' ideas are elicited and shared). This could be a manifestation of the presence of traces of positivist/authoritarian classroom environment which the teacher and students might be finding difficult to shed.

This paper has focused primarily on types of negotiation that occur between teacher and students rather than amongst students, largely because of the limitations of the microphone technology which couldn't record student-student negotiations within small groups (loud ambient 'noise' generated by mass student-negotiations). This is one limitation of the study and we suggest the need to look at student/student negotiation in the science practical class. Second, because this is a case study of a specially-chosen constructivist teacher, we cannot speculate whether other teachers (with different backgrounds) might behave in the same way. Therefore, we also recommend further studies of other constructivist teachers in order to test the viability of our 'grounded theory' about a typology of negotiation.

One question that could be asked as a result of this study is whether science affords particular negotiation opportunities or, put another way, would the negotiation we found in this study have occurred in a mathematics class or social studies class? The characteristics of science, especially relating to its inherent nature of practices and processes, point unarguably to its ability to be an appropriate medium for negotiation opportunities. The dynamics of the school science practical class and the structure of the practical sessions are usually such that social interaction, cooperation and negotiation are unavoidable. However, studies in mathematics (Wheatley, 1993), in writing (Davis, 1988), in literature (Mink, 1992) also indicate that negotiation occurs in other school subjects. We hazard a guess, however, that the scope and structure of negotiation might differ from subject to subject while the processes of negotiation remain common. Linn and Burbules (1993) have cautioned that, although group learning claims that students co-construct more powerful understandings than

they could construct alone, the diverse nature of the class indicates that this form of learning may not be the best mode of learning for all educational aims, for all subjects, or for all students. This could also apply to negotiation as a strategy for teaching within a constructivist environment given that it is a feature of group learning. Further research is certainly needed here as supporting evidence to how negotiations occur across the curriculum and they are used for teaching and learning.

Lastly, we could also ask if students would label what occurred in their science practical classes as negotiation, and whether they would agree with the categories of negotiation we have arrived at in this study. A replication of this study to find out students' perceptions and ideas about negotiation, and to further validate the various categories of negotiation found in this study would be in the right direction. As far as we are aware, this is the first study of its kind and it begs the need for more while serving to open the flood gate for more research studies.

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